# ECOLOGICAL STUDIES IN THE BAYS AND OTHER WATERWAYS NEAR LITTLE EGG INLET AND IN THE OCEAN IN THE VICINITY OF THE PROPOSED SITE FOR THE ATLANTIC GENERATING STATION, NEW JERSEY

Progress Report for the Period January-December 1974

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# INTRODUCTION

In September 1971, Ichthyological Associates, Inc. began an ecological study of ocean sites off Long Beach Island and Little Egg Inlet, New Jersey, for Public Service Electric and Gas Company. After 1 March 1972, sampling was restricted to the ocean in the vicinity of the proposed Site of the Atlantic Generating Station (AGS) and in the bays, rivers, and waterways from Manahawkin Causeway, Long Beach Island, to Atlantic City. The above areas are subsequently referred to as the study area. The vicinity of the Site is defined as an area from Holgate, Long Beach Island to off Brigantine Inlet and from the beach to approximately 6 miles from shore.

The AGS is to be located approximately 2.8 statute miles off the coastline (off Little Egg Inlet) at approximately 39°-28'-20" N latitude and 74°-15'-20" W longitude. Two 1150 MWe nuclear generating units will be placed on floating barges and protected by a large semicircular, rubble-mound breakwater. The area encompassed by the breakwater and plants is subsequently designated the Site.

The first objective of the study was to identity and describe the biota of the area both spatially and temporally. Subsequently, we attempted to determine if the Site was unique biologically, or if it supported particular concentrations of organisms. This has been done in part by comparing organisms found in a transect (inshore-offshore) across the Site with one both north and south of the Site. These two latter transects will later serve as control areas. A transect from the Mullica River through Great Bay to Little Egg Inlet has also been sampled to determine utilization of adjacent estuaries and movements of organisms between estuaries and the inshore ocean.

Additional samples for zooplankton and ichthyoplankton were taken inshore off Brant Beach, approximately 10 miles north of the Site; approximately 8 miles offshore of Brant Beach; and about 8 miles offshore of Little Egg Inlet. These areas are referred to as north and offshore of the study area. These collections were taken to help determine the extent of estuarine influence in the vicinity of the Site.

Regular sampling during 1975 was reduced to a monitoring program for juvenile and adult fishes, ichthyoplankton, zooplankton, and benthos. Fishes and macroinvertebrates were also collected for behavioral studies at the Brigantine Experimental Laboratory.

This progress report mainly covers the period January through December, 1974. Volume one includes the results of the 1974 sampling program for fishes and a section on the laboratory design and experimental procedures utilized at the Brigantine Experimental Laboratory. Volume two contains data on epifauna, marine algae, benthic invertebrates, protoplankton, and zooplankton. The section on protoplankton discusses results from collections made from May 1972 to April 1973. Data from individual collections for all programs are given in the Appendix Tables at the end of each volume. Physicochemical data pertinent to all biological collections in 1974 are included on pages 14 to 17 in Volume one. Results of a quantitative vegetation study along Great Bay

Boulevard are included in Volume three. Ecological studies done previously in the area by Ichthyological Associates, Inc. and others are discussed in Thomas et al. (1972), Thomas and Milstein (1973), and Ichthyological Associates, Inc. (1974).

Data for many of the sections are summarized by month and by season. Seasonal classifications are based on water temperature and are as follows: winter (January-March), spring (April-June), summer (July-September), and fall (October-December).

## SUMMARY

1. Biological studies were done in the vicinity of the proposed Atlantic Generating Station approximately 2.8 statute miles southeast of Little Egg Inlet.

2. Collections of fishes and invertebrates were taken in the Great Bay-Mullica River estuary; Little Egg and Beach Haven inlets; the ocean in the vicinity of the Site; and for plankton, in the ocean 10 nautical miles north of the Site and 8 nautical miles offshore.

3. The report mainly discusses and gives the results of the 1974 sampling programs; results for protoplankton are for studies conducted from May 1972 to April 1973.

4. A total of 73 species of epifauna was taken from substrate, trawl, clam dredge, and ponar grab samples in the vicinity of the Site.
   a. Seasonal variation in species composition, species diversity, and and biomass was evident from quarterly collections. In the first quarter, minimal colonization occurred; in the second quarter, density, diversity, and biomass were greatest; in the fourth quarter all parameters decreased.
   b. Variation with depth was apparent from quarterly collections. In the second and fourth quarters, colonization and biomass were greatest near the bottom.
   c. Hydroids and barnacles were the dominant colonizers in spring and summer on monthly retrieved cement panels. The numbers of barnacles and blue mussel spat were greatest in spring and early summer.

d. Communities on the tower near the Site were sampled after approximately 1 year. Dominant forms included algae near the surface, the blue mussel at mid depth, and anemones near the bottom. Species diversity values were greatest for mid depth collections.

5. Collections were made in Great Bay and Absecon Inlet to obtain standing crop estimates of important macro-algae.

a. The most commonly occurring algae in Great Bay were (in descending order of abundance) Ulva lactuca, Agardhiella tenera, Gracilaria foliifera, and Ceramium rubrum.

b. The alga which occurred most commonly on an intertidal rock jetty on Brigantine at Absecon Inlet was Enteromorpha linza.

6. Over 300 taxa of macroinvertebrates were collected in the ocean, bays, and inlets by ponar, clam dredge, 25-ft trawl and substrate plates.

7. Seventy-two ponar samples from the ocean and 29 from the Inlet were analyzed.

a. The average yearly density (mean density of all collections at a station for the year) of macroinvertebrates at different stations in the ocean ranged from $265/m^2$ to $8,245/m^2$.

b. In the ocean, at stations greater than 30 ft in depth polychaetes (Capitellidae, Asabellides oculata, and Scolecolepides viridis) dominated and at stations less than 30 ft in depth bivalves (northern dwarf tellin, Atlantic surf clam) dominated.

c. In the Inlet, the average yearly density at different stations ranged from $529/m^2$ to $3,325/m^2$. Bivalves were dominant, amphipods were common, and polychaetes were rare.

d. Seasonal trends of major community components in the ocean and Inlet were similar. Bivalve spat were dominant in the spring. In the summer and fall, polychaetes were most numerous in the ocean, and amphipods were most numerous in the Inlet.

e. Seasonal trends of the weight and number of major community components (bivalves, polychaetes, amphipods, and echinoderms) were similar.

8. Eighty-one clam dredge collections from the ocean, 47 from the Inlet, and 11 from Little Sheepshead Creek were analyzed.

a. In the ocean, the Atlantic surf clam ranked first; it composed 94% of the weight and 70% of the number of organisms taken. The Atlantic surf clam, horseshoe crab, lady crab, Atlantic moonsnail, rock crab, and sand dollar comprised 99.5% of the weight collected.

b. In the Inlet, the blue mussel, Atlantic surf clam, rock crab, and starfish made up 97.1% of the total weight.

c. In Little Sheepshead Creek, the hard clam, spider crab, and blood ark were the most common species taken.

d. Collections from the ocean and Inlet had a similar species composition. No significant differences were found between the stations for numbers of specimens of important species, except that the blue mussel was very abundant in the Inlet and sparse in the ocean.

9. In September, 45 samples were taken with a clam dredge to survey macroinvertebrate populations in the vicinity of the Site.

a. The Atlantic surf clam and sand dollar comprised 92% of the number and 95% of the weight collected.

b. The Atlantic surf clam was most dense off Brigantine Inlet ($1.6/m^2$) and averaged $0.18/m^2$ over the whole survey area. The average density at stations less than 20 ft in depth was $0.51/m^2$.

c. The mean length of 1,133 Atlantic surf clam was 101 mm. The mean length for the area inside the 20 ft contour was 98 mm and the mean outside this contour was 127 mm.

d. The 10 most numerous species, in descending order of abundance, were the sand dollar, Atlantic surf clam, Atlantic moonsnail, smooth astarte, morrhua venus, rock crab, lady crab, long-armed hermit crab, New England nassa, and northern moonsnail.

10. Some 202 collections were taken with the 25-ft trawl in the vicinity of the Site and 44 were made in Great Bay and Little Egg Inlet.

a. In the ocean, the 10 most abundant macroinvertebrates, by weight, were the horseshoe crab, rock crab, sand dollar, lady crab, starfish, Atlantic long-finned squid, sand shrimp, lion's mane jellyfish, blue crab, and spider crab.

b. Decapods constituted 67% of the total number and 35% of the total weight. The sand shrimp comprised 88% of the decapods collected.

c. In the Bay, the most abundant species, by weight, were blue mussel, boring sponge, rock crab, sand shrimp, blue crab, horseshoe crab, lady crab, red beard sponge, starfish, and hard clam.

d. In the ocean, the total n/coll. was greater at night than during the day. Most of this difference was accounted for by the sand shrimp.

11. Thirteen species of shellfish were taken commercially in the ocean and bays along the New Jersey coast in 1974. Their value, \$9.3 million, accounted for 50% of the value of commercial landings in New Jersey.

    a. Atlantic County accounted for 19% of the dollar value of New Jersey shellfish landings.

    b. The five most valuable species in New Jersey were the Atlantic surf clam, American lobster, hard clam, eastern oyster, and blue crab.

12. Aspects of the life history of the Atlantic surf clam are discussed.

    a. Most Atlantic surf clam spat (0.5 to 24.4 mm) were taken in spring, particularly in May. They were common at all ocean stations and the average yearly density was $152/m^2$.

    b. Small individuals of the Atlantic surf clam (15 to 99 mm) were collected from August through November. They were most abundant in August when the modal size class was 30-34 mm.

    c. Commercial-sized Atlantic surf clam ($>$ 100 mm) comprised 77% of the population on the Site transect and 58% in Little Egg Inlet. No seasonal trends in distribution were evident. Dense aggregations occurred near "G" buoy in the Inlet ($3.25/m^2$) and landward of the Site ($0.69/m^2$).

13. A total of 4,971 rock crab were collected with the trawl, lobster pot, ponar grab, and clam dredge and aspects of their life history are discussed.

    a. There appeared to be an inshore-offshore migration of large individuals. The rock crab was most abundant in the ocean in the summer and was most common in the bays and Inlet in the winter.

b. The ratio of males to females was 2.1:1, but fluctuations occurred seasonally. Male specimens ranged from 4 to 138 mm and females ranged from 3 to 91 mm.

c. Gravid females were most abundant in spring, and were collected in all months except July and August. They ranged from 22 to 77 mm.

d. Rock crab zoea were most abundant at the Site in May and were collected from early April to early June. Megalopae were collected at the Site from early-to mid-June and in September. Juveniles (3 to 9 mm) were collected in June and July.

14. Protoplankton collected from May 1972 through April 1973 are discussed.

a. Diatoms were most abundant in September (826,000 cells/l). Dominant species included Skeletonema costatum, Thalassiosira rotula, and T. condensata.

b. A secondary peak in diatom abundance occurred in February (248,000 cells/l). Thalassiosira nondenskioldii was the dominant species and Rhizosolenia fragilissima and Skeletonema costatum were subdominants.

c. Peaks in dinoflagellate abundance occurred in June and late August (239,710 and 384,390 cells/l, respectively). Several species of unidentified peridinians were grouped together and were numerically dominant in June. In late August, two unidentified gymnodinians and three Prorocentrum species were dominant.

d. Small coccoid blue-greens were always abundant, and ranged in density from 170,000 cells/l in December 1972 to 859,700 cells/l in June 1973.

e. Non-motile green algae ranged from 4,720 cells/1 in May to 37,370 cells/1 in early August.

f. Numbers of naked **flagellates** were lowest in April (23,400 cells/1) and highest during August (mean of 293,000 cells/1).

g. Tintinnids were the predominant ciliate group. Maximum abundance (15,000 cells/1) was in May and June.

15. Holoplankton and meroplankton were collected in surface, bottom, and oblique tows with a Clarke-Bumpus sampler (#20 nets).

a. Copepods were dominant at the Site during 1974 except in May when meroplankton predominated.

b. In the bays, copepods predominated all collections, except for the May collection at Brigantine Bays station #1, when meroplankton predominated.

c. <u>Oithona similus</u> was the only copepod that was found throughout the year at the Site in densities above 1,000/$m^3$.

d. Three general distribution patterns of copepods and other holoplankton were noted from ocean and bay collections:

1. "Estuarine and marine" forms had similar densities at the Site and bay stations, but were less numerous or absent from stations north and offshore of the study area.
2. "Euryhaline marine" forms were most abundant at ocean stations and usually showed little differences between these stations.
3. "Stenohaline marine" forms were found in greatest densities north and offshore of the study area and were usually absent or rare at bay stations.

e. Monthly copepod densities at the Site and at stations north and offshore of the study area were not significantly different.

f. Other holoplankters were more prevalent in the ocean than in the bays. Although densities were generally greater at the Brant Beach stations than at other ocean stations, these differences were not significant.

g. Bivalve larvae were generally the dominant meroplankton. Densities of bivalve larvae in the ocean usually exceeded those in the bay by a factor of from 2 to 10.

h. During night sampling at the Site in June, a maximum surface density ($150{,}426/m^3$) of gastropod larvae was found. Larvae of Melampus bidentatus, a snail restricted to the marshes, were dominant ($>$ 90%).

16. A total of 115 samples from the Site was examined for macrozooplankton. Thirty-eight samples from north and offshore of the Site were studied to determine whether the composition and density of macroplankters differed from those of the Site.

a. At the Site, the number of estuarine species was greater than that of oceanic species in every month. However, densities of oceanic forms were greater than those of estuarine forms during the spring and fall.

b. Offshore of Little Egg Inlet, oceanic species outnumbered estuarine species during all seasons except summer. Densities of estuarine forms were always very low. Offshore of Brant Beach, estuarine species outnumbered oceanic forms only in July but their densities were very small.

c. During the summer, the Site was an extension of the lower estuary where the spawning and development of many estuarine species, particularly crab and shrimp, took place.

d. The arrow worm, Sagitta elegans, was the dominant macroplankter at the Site during the winter and early spring; maximum densities of 345/$m^3$ (January) and 170/$m^3$ (April) were taken in bottom tows.

e. Zoeal stages of the sand shrimp, Crangon septemspinosa, were collected throughout most of the year at the Site and were most numerous in May (69/$m^3$, bottom). They were generally less common at stations north and offshore of the study area.

f. Zoeae of the grass shrimp, Palaemonetes spp., were common at the Site during the summer and were most abundant in July (265/$m^3$, bottom), especially in daytime bottom tows.

g. Crab larvae were collected at the Site from March through November and comprised most of the macrozooplankton taken from June through August. Densities of crab larvae were generally lower at stations north and offshore of the study area where larvae of hermit crabs, fiddler crabs, and mud crabs were sparse.

h. Zoeae of the blue crab, Callinectes spp., were occasionally taken in June, July, and September at the Site. The maximum density of 21/$m^3$ was taken in a surface collection at night in July. Megalopae were present from August through October at the Site and were most numerous (8/$m^3$) in September.

i. Zoeae and megalopae of the rock crab, Cancer irroratus, were collected at all ocean stations but were most common at the stations north and offshore of the study area.

# EPIFAUNA

Martha M. McCullough

## Introduction

The epifauna program was initiated to determine the species composition and biomass of fouling communities in the vicinity of the Site. Masonite panels were affixed to the weather tower 0.5 nautical miles SSW of the Site at three depths and removed monthly during 1973 (McCullough 1974).

In 1974, the program was designed to indicate variations in colonization with season, depth, and texture of concrete substrates. Epifauna living on a submerged leg of the weather tower were sampled to gain information pertaining to prolonged fouling on an epoxy-coated steel substrate.

## Materials and Methods

### Concrete Substrate

#### Quarterly Collections

On 2 January 1974 an array was deployed approximately 3.5 mi SE of Little Egg Inlet, 0.6 nautical miles seaward of the Site, in 45-50 ft of water. Cement test-blocks of 36 x 40 x 5 cm were affixed at 6, 17, and 40 ft below MLW (Fig. 1). The array was retrieved on 25 March, 24 June, 27 September, and 6 December. Two scrapings of equal area were taken from the upper, lower, and side surfaces of each block. New test-blocks were affixed and the array redeployed.

The surface buoy marking the array's location was lost during the second quarter. It was relocated and moved when the second collection was taken on 24 June. A location 2.8 nautical miles SSE of Little Egg Inlet was chosen to facilitate more frequent checks of the array. It remained at this location until the end of 1974 when it was removed.

### Monthly Collections

Concrete panels having a surface area of 570 $cm^2$ were made using wooden molds. The side of the panel at the open end of the mold was more irregular than the other side. Panels were weighed before deployment at surface, mid depth, and bottom.

The array was used from 23 April to 6 September. Duplicate panels were retrieved monthly and every two months. Upon retrieval the plates were placed in plastic bags. These were replaced by fresh panels. Because of disturbance of the surface panels due to waves and water turbulence, only mid depth and bottom collections were taken (Fig. 1).

## Epoxy-coated Steel

During the first week of June 1973 an epoxy coated steel weather tower was installed near the Site. A year later on 5 June 1974, scrapings of epifauna were taken by divers from a leg of the tower. A three dimensional plexiglass "Submerged Epifauna Collection Shield" was built to insure collection of the specimens after they were removed from the leg (Fig. 2). The biota were placed in a bag with 1-mm mesh netting. Two scrapings were taken at 15 and at 30 ft below MLW. Although the sampling was done after 2 consecutively calm days, surge near the ocean surface interfered with collections, and only one sample was taken from 5 ft below MLW.

Miscellaneous Collections

Epifauna was collected intermittently by clam dredge and 25-ft trawl. Subsamples were kept and analyzed in the laboratory.

Preservation of Samples and Analyses

Organisms were anesthetized with $MgCl_2$ on retrieval and after a few hours, were preserved with 20% formalin.

Identification, enumeration, and dry weight were determined in the laboratory. For samples scraped from concrete blocks and steel, dry weights were determined, by species, after drying at 100 C. The concrete panels were dried at 100 C and weighed. Organisms which separated from the panels were filtered from the preservative with a 1-mm mesh net, dried at 100 C, enumerated, and weighed. Any weights less than 0.001 g were noted by a plus.

Randomly selected sub-samples of the blue mussel, *Mytilus edulis*, from the tower were measured to the nearest mm. Organisms were sorted initially by visual examination. A binocular microscope was used to examine the hydroid and mussel fractions while searching for small, associated organisms. Final identifications and counts were made by the use of a binocular or compound microscope. Species diversity values were calculated using Brillouin's index (Pielou 1966a). Values were calculated for all samples using the formula:

$$H = \frac{1}{N} \log \frac{N!}{N_1!\, N_2! \ldots N_s!}$$

where H = species diversity, N = total number of specimens of the ith species, and S = number of species.

## Results

Seventy-three species were collected at and in the vicinity of the Site during 1974 (Table 1). Species taken with gear used for sampling fishes or benthic invertebrates (Tables 2 and 3) were noted in the record as present.

### Concrete

#### Quarterly Collections

The blocks located closest to the surface were always missing at the time of quarterly collection. All test substrates were missing from the array for the third quarter samples due to corrosion of the equipment.

Seasonal variation was evident in the collections taken quarterly from concrete substrates (Table 4-8). Minimal colonization occurred in the first quarter when water temperatures at the Site ranged from 1 to 7.2 C. Collections from the second quarter contained large numbers of the barnacle, *Balanus eburneus*; hydroids, *Tubularia crocea* and *Obelia flabellata*; and the caprellid amphipod, *Aeginina longicornis*. Temperatures during the second quarter rose from 6 C to 21.5 C. *Caprella equilibra*, and the above two hydroids were present in the fourth quarter and a large number of blue mussel spat was present in all collections. Nudibranchs were noticeably more abundant during the fourth quarter.

Dry weights were greater during the second quarter than in the fourth quarter due to the presence of barnacles (Fig. 3). Second quarter weights adjusted to an average of $g/m^2/90$ days were 177.6 at middepth and 697.8 at the bottom, while those from the fourth quarter were 3.2 and 247, respectively.

Variation in colonization with depth was also apparent. In both the second and fourth quarters, it was greater near the bottom, and particularly for hydroids, blue mussel, and barnacles. Hydroids showed marked differences with depth. *Obelia* dominated collections at middepth and *Tubularia* dominated near the bottom. Dry weights reflected the heavier growth near the bottom.

Species diversity values were greater in the second quarter collections than in the fourth quarter (Tables 5-9). This appeared to be due to the overwhelming dominance of blue mussel in the fourth quarter.

## Monthly Collections

Hydroids and barnacles were dominant colonizers on the cement panels deployed monthly from 23 April to 6 September (Tables 9-11).

Amphipod abundance appeared to increase when hydroids were abundant. Blue mussel and barnacle settlement was greatest from late spring to early summer. Among caprellid amphipods, Caprella equilibra gradually replaced Aeginina longicornis during the summer.

Weights were greater for bottom collections from April to July (Fig. 4), when barnacles and hydroids were most abundant. From July to August, the marked decrease in weight of bottom collections was attributed, in part, to the absence of barnacles. Encrusting bryozoans colonized the bottom plates at this time, but they were less abundant at middepth where hydroids and barnacles occupied much of the available space. Dry weights of collections at middepth showed a continued decline from April to September (Fig. 4).

Species diversity values (Tables 9-11) were largest for monthly collections taken from 23 May to 1 July. This may be due in part to the long period of exposure for these panels and the rising water temperatures. Colonization was greater on the rough surface of each panel (Tables 12 and 13).

Epoxy-coated Steel

The communities sampled on the tower near the Site were established during the preceding year. The area of maximum growth and largest species diversity was at middepth, where the blue mussel dominated (Table 14). The occurrence of algae on the tower leg near the surface of the water reduced the area of suitable substrate for epifauna. Middepth conditions were more suitable. Near the bottom, the anemone, Metridium senile, was dominant. Other species were located in the narrow spaces between individual anemones. The latter were attached to dead barnacles and other debris which formed a layer on the tower. The bottom 1 to 2 ft of tower surface was bare.

Large blue mussel (>30 mm) were found exclusively at middepth (Fig 5). Generally smaller specimens were found near the surface. The small size of mussels from near the bottom was apparently due to the abundance of anemones. The normally expanded condition of *Metridium* may have reduced water circulation in the spaces where mussels were attached and interfered physically with their feeding.

Species diversity values were larger at middepth (0.78 and 0.81) than at the surface (0.22) or bottom (0.42 and 0.65) due to the abundance of both blue mussel and *Jassa falcata* (Table 14).

Miscellaneous Collections

Occasionally, hydroids, a bushy bryozoan, and associated organisms such as the blue mussel spat and polychaetes were found in trawl samples (Table 2). The branching hydroids, *Obelia flabellata* and *Thuiaria argentea*, and branching bryozoan, *Amathia vidocivi*, afforded sites for spat attachment. The polychaete, *Autolytus cornutus*, secretes a delicate tube which was found entwined with *Obelia* and *Thuiaria* stems. Amphipods and mysids were not effectively sampled by trawl. Trawl collections however, revealed the presence of species which were lacking or sparsely represented in the collections from artificial substrates (Table 15).

Epifauna found in some clam dredge samples were generally sessile (Table 3). *Thuiaria*, encrusting bryozoans (*Schizoporella unicornis* and Electra hastingsae), blue mussel, and barnacles were found attached to shells. The polychaetes, Saballaria vulgaris and Hydroides dianthus, constructed their tubes on shells. Few motile organisms occurred.

On several occasions, epifauna were collected by chance. On 5 August, a peice of iron was taken in a trawl collection. Hydroids, bryozoans and barnacles were growing on it. One specimen of a shrimp, Hippolysmata wurdemanni was among the hydroids. Its northern range was noted previously as 38° N (Gosner 1971).

Scrapings taken on 3 September from a terry-cloth bedroom slipper found floating at the Site contained the goose barnacle, Lepas anatifera, and amphipod, Microprotipus raneyi. Neither were taken in any other epifauna samples. Caprella penantis and campanularid hydroid fragments were also present.

## Discussion

Dry weights for epifauna collected on concrete indicated greatest growth from late May to early July (Figs. 6 and 7). The species diversity value was also larger then (Tables 5-11). Hydroid colonization occurred in varying degrees throughout the year (Tables 4-11). Fewest hydroids were collected during the first quarter. The occurrence of larger epifaunal organisms such as barnacles, mussels, and anemones seemed to be seasonal. Since barnacles settled in greatest numbers during the period of increased hydroid colonization (Tables 5, 6, 9, 10 and 11), solid substrata were equally available to both. The hydroids that were already established at the time of settling of blue mussel provided points of attachment for the spat. These spat were numerous in the fourth quarter collections (Tables 7 and 8). Their large number reduced species diversity values.

Amphipod occurrence was often positively associated with hydroid abundance (Tables 5, 6, 9, 10, and 11). An exception was the large number of the amphipod, Jassa falcata, found in collections from the tower that were dominated by blue mussel (Table 14). Mussel byssus threads were dense in these collections and served as a habitat for amphipods.

Although they were not as numerous as crustaceans, polychaetes were more conspicuous in samples from the tower which were dominated by blue mussel and anemones (Table 14). The chief exception was Autolytus cornutus which attached its tubes to hydroid and bryozoan stems.

Hydroids and amphipods were more characteristic of initial epifaunal colonization than of established communities. The hydroids provided substrate for blue mussel which later became dominant. Its heavy settling toward the end of the year gave it a competitive advantage over other species in winter (Tables 7 and 8 and McCullough 1974). By the time competing organisms increased during spring and summer, the blue mussel was dominant.

# MARINE ALGAE

Richard P. Smith

## Introduction

Collections were made in Great Bay and Absecon Inlet to obtain estimates of the standing crop of dominant macroalgae in the study area. Samples from Great Bay contained benthic and subtidal algae. Algae collected from a rock jetty in Absecon Inlet included intertidal species found on hard substrates throughout the study area.

## Materials and Methods

### Benthic Algae

Samples were taken in March and April with a biological dredge. Stations sampled in Great Bay corresponded to trawl zones (see Fig. 13, Vol. I). Collections in June and July were taken with a 9-ft semiballoon trawl because the dredge damaged delicate algae. The trawl also covered a larger area and did not dig into soft substrates.

In each sampling zone a buoy was anchored adjacent to a permanent structure. A second buoy was located 50 yards away using a rangematic distance finder. The dredge or trawl was then hauled at a constant RPM along the 50-yard transect. Total bottom area covered by the trawl was approximately 127 $m^2$. Algae were preserved in 5% formalin, sorted, and weighed ($gm/m^2$) in the lab.

### Intertidal Algae

A 600-yard rock jetty, lying in a SE-NW direction at the south end of Brigantine was sampled at low tide from January through September. The surf was rough along the jetty's north wall so the south wall, which bordered Absecon Inlet, was sampled.

Scrapings were taken from several 20-$cm^2$ grids which were randomly sited on the inshore one-third of the jetty. These were sorted and mean dry weights of species were recorded ($gm/cm^2$). The rest of the jetty was examined visually and an estimate of major algal species was made.

Bay samples were recorded as wet weights because of their bulk; weights were obtained after blotting excess water from the algae.

Species collected for the first time in this study area were either dried and mounted on herbarium paper, or preserved in buffered 5% formalin (Table 16). Species were identified by using Dawson (1956) and Taylor (1957).

## Results

### Benthic Algae

The most abundant alga by percent area covered and by frequency of occurrence taken in Great Bay was Ulva lactuca. Ulva comprised 61% of the total weight of algae taken in June and 73% for July. From June to July, its weight more than tripled (Table 17).

Agardhiella tenera and Gracilaria foliifera both ranked second by weight. In June, these species were present only in zones 1010 and 1200 but in July, they were more widespread. Wet weights also increased in most zones from June to July (Table 17).

The third most common species was Ceramium rubrum. This red alga was present in zones 2200 and 1200 in June. The wet weight at zone 1200 was similar in June and July but was greater at zone 2200 in July (Table 17).

In July, more species were collected in most zones (Table 17). Large weight increases of Ulva and Gracilaria were recorded in zone 2200; this zone had the greatest percentage of algal weights for July (Table 17).

In Great Bay 58% of the algal species collected were Rhodophyta (red algae), 28% were Chlorophyta (green), and 14% were Phaeophyta (brown).

Intertidal Algae

The most abundant species found on the rock jetty in Absecon Inlet was Enteromorpha linza. This green alga was found throughout the sampling period at both intertidal and subtidal levels. It occurred most often in spring, and its greatest biomass was in June (Table 18).

Enteromorpha minima was second in abundance and density. It occurred most frequently and was most abundant in March (Table 18).

Bangia fuscopurpurea was found near the mean high water mark. It occurred most often in summer and had a maximum biomass in July.

Urospora penicilliformis was found near the mean low water mark. It was collected from March through May and was most common in April (Table 18).

The maximum biomass of Porphyra umbilicalis was in March. It grew in the same zones as Enteromorpha minima and Urospora penicilliformis. It was absent from May, June, and September collections (Table 18).

Enteromorpha minima and Enteromorpha linza were abundant on the offshore two-thirds of the jetty. Enteromorpha linza, the blue mussel (Mytilus edulis), and barnacle (Balanus balanoides) inhabited the lower intertidal regions.

Of all algae collected on the jetty, 67% of the weight was Chlorophyta, 22% was Rhodophyta, and 11% was Phaeophyta.

## Discussion

Zonations of algae were distinct on the Absecon Inlet jetty but were less well defined on a gentle sloping shoreline in Great Bay.

Those algae found in the intertidal regions are subject to intermittent periods of dessication, rapid changes in salinity, seasonal and daily temperature changes, and wave turbulence which may result in stunted growth. For example, Enteromorpha linza collected from Great Bay in July measured approximately 24.0 cm while specimens collected from the jetty in the same month, measured approximately 2.0 cm. Those specimens of Porphyra umbilicalis from the bays were much larger than those exposed to wave turbulence on the jetty.

Interspecific competition may occur between Urospora penicilliformis, Enteromorpha minima, and Porphyra umbilicalis which occupy the same zone. Some seasonal differences in biomass between these species were noted (Table 18).

# BENTHIC INVERTEBRATES

Elizabeth V. Garlo, Jeffrey J. Hondo, and Gerald J. Miller

Benthic Invertebrates were collected in Little Sheepshead Creek, Little Egg Inlet, and the vicinity of the Site in 1974 (Table 19). Collections taken at regular time intervals were made with a ponar grab, clam dredge, and 25-ft trawl. An intensive survey was conducted with the clam dredge in September.

## PONAR GRAB

### Introduction

Since February, 1972, quantitative samples have been collected with a ponar grab in the vicinity of the Site and cable route. The program was described in Thomas and Milstein (1973) and Garlo et al. (1974). The objectives were to determine the spatial and temporal distribution of infauna communities, the number of organisms per $m^2$, and the dry weight of organisms per $m^2$ at selected stations.

In the ocean, the five stations which were sampled monthly (Fig. 8, Table 20) were located as follows: one north of the Site (zone 5143), one south of the Site (zone 5165), and three in an inshore-offshore transect from the 15-ft contour to the Site (zones 5158, 5152, and 5255). The five stations sampled quarterly were as follows: landward of Site (zone 5258), Site (zone 5254), the Ridge (zone 5252), and two stations landward of Brigantine ridge (zones 5180 and 5282).

In the Inlet, monthly samples were taken from a station east of Stake "96" (zone 1010 near "G" buoy), and quarterly samples were taken from stations near "F" buoy (zone 1010) and off Little Beach (zone 1020).

## Materials and Methods

One drop of the ponar sampled an area of bottom substrate of 23 x 23 cm or 0.05 $m^2$. Thirty pounds of extra weight was added to the ponar to facilitate its penetration into the substrate. The ponar was lowered by means of a davit and electric windlass. Each sample was put into calibrated buckets and the volume was recorded; samples smaller than 0.9 liters were usually discarded. The sample was poured into a removable 1-mm mesh nylon net set in a stainless steel frame, and was washed with running seawater. The screen and contents were then removed from the frame. Organisms were relaxed in 5% $MgCl_2$ and seawater for 1 to 5 hours. Samples were later fixed in 5% formalin for 24 to 72 hours, washed, and stored in 70% isopropanol and 5% glycerol. Rose bengal was added to samples to facilitate separation of organisms from the sediment. All organisms were identified and enumerated. Nomenclature usually followed that of Gosner (1971), Bousfield (1973), or Pettibone (1963).

Sediment samples were taken at each station by making an extra drop of the grab and removing a 500 cc subsample. They were washed in freshwater to remove salt and dried in an oven at a low temperature. Grain size analysis was performed on sediment samples from ocean stations using U. S. Standard Testing Sieves at 1/4 Ø intervals according to the procedures described by Folk (1968).

Dry weight was determined for preserved specimens from all samples taken at the Site (zone 5255) and east of Stake "96". The calcareous shells of molluscs were dissolved in 50% HCl. Each taxon was dried at 100 C until a constant weight was reached (approximately 16 hours), cooled in a desiccator, and weighed to 0.1 mg on a Mettler balance.

The species diversity for each collection was determined with Brillouin's index (Pielou 1966 ). Seasonal and yearly diversity values are averages of individual values.

The variability between successive drops of the ponar was examined. Replicate samples were taken at one station in the ocean (zone 5152) and one in the Inlet (zone 1010) in February, May, August, and November. Ten grabs were made while anchored at each station and the samples were preserved separately. Organisms from each grab were identified and enumerated. The observed cumulative percent species for each grab in the replicate series was calculated. The expected cumulative percent species was calculated by randomizing the observed values 3 times and taking the mean and standard deviation of the observed and random values.

A modification of the Kolmogorov-Smirnov test (Garlo et al. 1974) was used to set confidence limits on the entire cumulative frequency distribution. The Kolmogorov-Smirnov goodness of fit test (Sokal and Rohlf 1969) was used to test for differences between observed and expected cumulative frequency distributions and between expected frequency distributions by season.

# Results

## Sampling Variability

The observed values for the cumulative percent species curve and the expected values were plotted for each station by season (Figs. 9 and 10). A more detailed explanation of the method of calculating the cumulative frequency distribution can be found in Garlo et al. (1974).

Curves of the observed values for cumulative species from the replicate series began to level off after a 0.25 $m^2$ area of bottom substrate was sampled. No differences ($P \leq .05$) were found between the observed and expected relative frequency distributions and between expected relative frequencies by season at a station.

The area sampled at each regular station was 0.35 $m^2$ in the ocean and 0.25 $m^2$ in the Inlet. Confidence limits of the expected values at each station by season and for the year are given in Tables 21 to 23. In the ocean, the expected mean cumulative percent species was $87 \pm 15$. The mean of the observed values was 87% and they ranged from 74% in winter to 93% in spring. In the Inlet, the expected mean cumulative percent species was $83 \pm 26$. The mean of the observed values was 87% and they ranged from 71% in summer to 100% in winter.

Ninety-two samples taken in the ocean and Inlet in 1974 yielded 24,845 specimens. The species composition, weight (at selected stations), species diversity, and physicochemical parameters for each collection are given in Appendix Tables 1 to 6 and Tables 24 to 30. Seasonal summaries of monthly collections appear in Tables 31 to 36. Average yearly density ($n/m^2$) of the most abundant species is presented in Table 37. The grain size classification of the sediment samples taken with each collection from the ocean is given in Table 38.

Ocean

In the ocean, 72 samples yielded 19,204 specimens. The average yearly density (number of specimens/$m^2$) at individual stations ranged from 265 n/$m^2$ on the Ridge (zone 5252) to 8,245 n/$m^2$ landward of the Site (zone 5258) and for all stations was 1,600 n/$m^2$. Yearly average species diversity values ranged from 1.64 to 2.16.

Some 47% (906 n/$m^2$) of the specimens were polychaetes, 27% (508 n/$m^2$) were bivalves, 14% (267 n/$m^2$) were amphipods, and less than 1% (1 n/$m^2$) were echinoderms. The 10 most common taxa were Capitellidae (404 n/$m^2$); northern dwarf tellin, *Tellina agilis* (329 n/$m^2$); *Asabellides oculata* (202 n/$m^2$); *Protohaustorius deichmannae* (156 n/$m^2$); Atlantic surf clam, *Spisula solidissima* (152 n/$m^2$); *Scolecolepides viridis* (98 n/$m^2$); *Neomysis americana* (63 n/$m^2$); *Gammarus lawrencianus* (37 n/$m^2$); *Magelona rosea* (32 n/$m^2$); and *Acanthohaustorius millsi* (25 n/$m^2$).

Seven of the ocean stations had an average yearly density of between 700 and 2,000 n/$m^2$; average yearly diversity values ranged from 1.64 to 2.04.

At depths of less than 30 ft (zones 5158, 5152, and 5161), the bottom was generally fine to very fine sand with less than 4.5% silt. In these areas, bivalves were most abundant, polychaetes were common, and amphipods were sparse. At depths greater than 30 ft (zones 5258, 5255, 5254, and 5143), the bottom type was fine to coarse sand with 4.5 to 19% silt. Polychaetes were the dominant organisms at these stations, bivalves were common, and amphipods were sparse.

Samples from the Ridge (zone 5252) and near the Brigantine ridge (zone 5282) had an average yearly density of less than 500 $n/m^2$. Yearly average species diversity was 2.00 and 2.16, respectively for the two stations. The bottom substrate ranged from medium to coarse sand with less than 1% silt. Densities of all species were low. Bivalves were most abundant at the Ridge and polychaetes were most common near the Brigantine ridge.

The station landward of the Site (zone 5258), which was located in a trough where the depth was usually greater than 30 ft, had the highest average density (8,245 $n/m^2$). The average diversity for the year (1.66) was relatively low. The bottom substrate ranged from coarse to very fine sand with 3% silt. Polychaetes were dominant, bivalves were common, and amphipods were sparse.

Seasonally, the density of organisms on the Site transects was highest in the spring (2,938 $n/m^2$). Bivalve spat comprised 41% of the specimens collected. In summer, the density (1,865 $n/m^2$) was less due to a decline in bivalves but the number of polychaetes increased and comprised 42% of the specimens collected. In the fall, the density was lowest (668 $n/m^2$). It rose to 907 $n/m^2$ in the winter when bivalve spat comprised 43% of the specimens collected (Fig. 11).

Capitellid polychaetes ranked first in abundance at ocean stations and were found at all stations except zone 5282. They formed dense aggregations and had a yearly average of 4,064 $n/m^2$ at the station landward of the Site (zone 5258). The average density for the year for all stations was 406 $n/m^2$. Maximum density occurred in September.

The northern dwarf tellin was second in abundance and was collected at all stations in the ocean. It formed a dense aggregation landward of the Site (zone 5258). Maximum densities of from 205 to 1,572 n/m$^2$ were observed in May or June at all stations.

Ampharetid polychaetes, Asabellides oculata, ranked third in abundance at ocean stations and were collected at all stations except the Ridge. They formed a dense aggregation landward of the Site and averaged 1,463 n/m$^2$ for the year. They were most abundant at all stations in May and June.

The amphipod, Protohaustorius deichmannae, ranked fourth in abundance and was found at all ocean stations. It was most abundant at the stations closest to the Inlet (zones 5161 and 5158). Peaks of abundance occurred in June, July, and February.

The Atlantic surf clam ranked fifth in abundance and was collected at all stations in the ocean. A dense aggregation occurred at the stations landward of the Site. The greatest densities occurred in May and ranged from 81 to 1,709 n/m$^2$. A minor peak in abundance occurred from November through March.

Little Egg Inlet

In the Inlet, 29 samples taken at 3 stations yielded 5,641 specimens. The average yearly density of specimens ranged from 529 n/m$^2$ at the station off Little Beach (zone 1020) to 3,325 n/m$^2$ near "F" buoy (zone 1010). Average yearly diversity values ranged from 0.74 to 1.59.

Some 82% (4,626 n/m$^2$) of the specimens collected were bivalves, 14% (788 n/m$^2$) were amphipods, and 2% (85 n/m$^2$) were polychaetes. The

10 most common taxa were the blue mussel, Mytilus edulis (4,353 $n/m^2$); Parahaustorius longimerus (328 $n/m^2$); Acanthohaustorius millsi (226 $n/m^2$); northern dwarf tellin (160 $n/m^2$); Atlantic surf clam (106 $n/m^2$); Protohaustorius deichmannae (61 $n/m^2$); Magelona rosea (22 $n/m^2$); Neomysis americana (20 $n/m^2$); Gammarus lawrencianus (19 $n/m^2$); and Scolecolepides viridis (11 $n/m^2$).

The density of organisms was highest in the spring (5,772 $n/m^2$). Bivalve spat (primarily blue mussel) comprised 94% of the specimens collected. In summer, the total density was less (842 $n/m^2$) due to the disappearance of most blue mussel spat. Density was lowest in the fall when amphipods comprised 65% of the community sampled; density increased in the winter when bivalve spat comprised 73% of the total (Fig. 12).

Spat of the blue mussel ranked first in abundance in Inlet collections and they were collected at all stations. They were most abundant near "F" buoy on a rubble and sand bottom. Off Little Beach and east of Stake "96", blue mussel spat were usually collected on detached vegetation or hydroids. The highest densities of spat were collected in spring.

Parahaustorius longimerus ranked second in abundance and occurred at all stations in the Inlet. It was most abundant near "F" buoy and the highest densities (185 to 370 $n/m^2$) occurred in late summer and early fall.

Acanthohaustorius millsi ranked third in abundance and occurred at all stations in the Inlet. The highest densities (117-227 $n/m^2$) occurred in summer.

The northern dwarf tellin ranked fourth in abundance and was taken at all stations in the Inlet. It was most abundant at the station east of Stake "96" where the sediment consisted of fine sand with a small percentage of silt. The largest densities (15 to 941 n/m$^2$) occurred from May through August.

The Atlantic surf clam ranked fifth in abundance and was found at all stations. It was most abundant east of Stake "96". The largest densities (38 to 71 n/m$^2$) occurred from May through August.

Biomass

Biomass (standing crop) estimations were made at the Site, zone 5255, and in the Inlet, zone 1010 (Tables 33 and 36). Trends exhibited by the weight and number of major community components (bivalves, polychaetes, amphipods, and echinoderms) were similar except in one case. In the winter, a small number of large sized polychaetes comprised most of the weight (Fig. 13).

At the Site, the average seasonal biomass ranged from 1.510 g/m$^2$ in the winter to 3.445 g/m$^2$ in the summer. The yearly average was 2.058 g/m$^2$. Polychaetes comprised 46% and bivalves comprised 12% of the yearly biomass. The 10 groups which comprised most of the weight were the New England nassa, Nassarius trivittatus; Nephtys bucera; northern moon snail, Polinices heros; Polychaeta fragments; northern dwarf tellin; rock crab, Cancer irroratus; Scolecolepides viridis; Asabellides oculata; Pherusa affinis; and Lumbrineris fragilis.

In the Inlet, the average seasonal biomass ranged from 0.201 g/m$^2$ in the winter to 18.306 g/m$^2$ in the spring. The yearly average was

5.716 $g/m^2$. Bivalves comprised 83%, amphipods 2%, and polychaetes, 1% of the biomass (Fig. 12). The large increase in biomass in spring was due to a set of blue mussel. The seven groups which comprised most of the weight were the blue mussel; long-armed hermit crab, *Pagurus longicarpus*; unidentified fragments; sand shrimp, *Crangon septemspinosa*; *Acanthohaustorius millsi*; *Diopatra cuprea*; and rock crab.

## Discussion

Specimens which are abundant in ponar collections are permanent residents whose numbers are not influenced by seasonal migration. Biomass and density are subject to seasonal changes due particularly to setting, recruitment, and mortality.

Stations ranged in depth from 13 to 42 ft in the ocean and from 5 to 25 ft in the Inlet. Stations in the Inlet were subject to more surge, greater tidal current velocity, and more shifts in substrate than stations in the ocean. The harsh conditions contributed to the generally lower densities and diversity values in the Inlet. The blue mussel dominated collections in the Inlet by weight and number.

Ocean stations were classified into two general groups according to species composition. Stations greater than 30 ft in depth which had a higher silt content than other stations were dominanted by polychaetes (Capitellidae, *Asabellides oculata*, *Scolecolepides viridis*). Stations less than 30 ft in depth which contained low percentages of silt were dominanted by bivales (northern dwarf tellin, Atlantic surf clam).

At all stations in the Inlet, bivalves (blue mussel) were dominant, amphipods were common, and polychaetes were rare.

Seasonal trends of the major community components both in the ocean and in the Inlet were similar. Bivalve spat (blue mussel, northern dwarf tellin, Atlantic surf clam) were dominant in spring. Their numbers declined in summer and fall but increased slightly in winter. In the summer and fall, polychaetes (Capitellidae, *Asabellides oculata*) were most numerous in the ocean and amphipods (*Parahaustorius longimerus*, *Acanthohaustorius millsi*) were most common in the Inlet.

## CLAM DREDGE

### Introduction

Since April, 1972, benthic infauna was collected with a clam dredge in the vicinity of the Site and cable route (Thomas and Milstein 1973, and Garlo et al. 1974). In 1974, the program included stations in the ocean, Little Egg Inlet, and Little Sheepshead Creek (Table 20). The major objectives were to determine the spatial and temporal distribution and the relative abundance and weight of benthic infauna.

### Materials and Methods

The clam dredge consisted of a steel frame (3 x 2 x 1 ft) and a 3.5-ft long polypropylene bag which had a chain bottom. The largest mesh (1.5-inch) in the bag was at the codend and the smallest (3/4-inch) was on the top and sides of the bag. The dredge was towed in the direction of the prevailing wind or tide and dug approximately 4 to 6 inches into the sediment. In the ocean the dredge was retrieved by means of a gantry and hydraulic winch. In the Inlet and Creek, it was retrieved by means of a davit and electric windlass.

Clam dredge collections were quantified by estimating the distance towed. Position at the beginning and end of selected 15-minute tows was determined by plotting sextant or mini-ranger readings on a chart. The mean distance towed was calculated from 23 hauls taken at regular stations in 1974. The average 15-minute tow taken in the ocean covered 184 $m^2$ ($\pm$ 41 $m^2$, $P \leq .05$). The distance towed during 5-minute hauls in Little Egg Inlet and Little Sheepshead Creek in 1973 was determined by dropping buoys at the start and finish of each haul. The distance between them was measured with a marked rope. The area covered at 3 stations in the Inlet was approximately 28 $m^2$ and at 2 stations in Little Sheepshead Creek it was approximately 17 $m^2$.

In the field, abundant species such as the Atlantic surf clam, blue mussel, and sand dollar were counted, weighed (with a hand-held spring scale) to the nearest 0.1 kg, and released.

Small collections and subsamples of abundant species were returned to the laboratory. Selected specimens were relaxed in 10% $MgCl_2$ for 1 to 5 hours, fixed in 10% formalin for 24 to 72 hours, washed, and transferred to 40% isopropanol. Preserved specimens were identified, enumerated, and weighed. The wet weight was measured to the nearest gram with an Ohaus triple beam balance.

In the field and the lab, anterior-posterior length of the hard clam and surf clam, and carapace width of the rock crab were measured to the nearest millimeter with a vernier caliper. The gonad condition of the Atlantic surf clam was estimated each month by macroscopic examination. A randomly selected subsample of 10 to 35 clams from one collection in the ocean and one in the Inlet was examined (Table 39). The sex and reproductive condition of all crabs were recorded. Nomenclature usually followed that of Gosner (1971).

The yearly total number per collection (n/coll.) of major invertebrate components (gastropods, bivalves, decapods, echinoderms, and the sum of all other species combined) was ranked and compared with the nonparametric Friedman's test (Tate and Clelland 1957). Differences between ocean stations, Inlet stations, and offshore and Inlet stations were compared.

Replicate hauls of a clam dredge were made by taking two successive tows over the same area in the vicinity of the Site and in Little Egg Inlet in 1974 (Table 40). Numbers of the Atlantic surf clam taken in 23 replicates were compared graphically and with the Wilcoxon signed rank test (Tate and Clelland 1957). The formula, $R_T = \frac{(R_1 - R_2)}{(R_1 + R_2)/2}$, was plotted versus $\log \frac{R_1 + R_2}{2}$ where, $R_1$ equals the number of clams in replicate 1, $R_2$ equals the number of clams in replicate 2, and $(R_1 + R_2)/2$ equals the average size of the haul. The linear regression equation was calculated with 15 pairs of data (zero values and outliers were deleted). An approximate relation between sample size and amount of variation between hauls in the same area was determined.

# Results

## Sampling Variability

The Wilcoxon test indicated that the variation between replicate hauls was random. The percent variation was greater in areas with low density (Fig. 14). In samples with less than 10 clams, 100% sampling variation occurred. In larger samples, with more than 100 clams, sampling variation was 25% or less.

## Ocean

In 1974, 81 collections were taken in the vicinity of the Site (Fig. 8). They yielded 4,427 specimens of 41 taxa which weighed 485 kg. Species composition and physicochemical parameters for each collection are given in Appendix Tables 7 to 15. Seasonal summaries of monthly collections appear in Tables 41 to 49. The Atlantic surf clam ranked first and comprised 94% of the weight and 70% of the specimens. Other major species were the horseshoe crab, *Limulus polyphemus* (2% by weight, 0.2% by number) and the Atlantic moonsnail, *Polinices duplicata* (2%, 7%). The remainder was accounted for by 38 taxa, each of which comprised less than 1% of the total weight.

Ocean stations were compared by ranking the major components of the collections. No significant difference ($P \leq .05$) between stations was found when comparing major components with Friedman's test. Ocean stations were also compared by ranking the total yearly density of the 7 most abundant species. No significant difference was found ($P \leq .05$) between stations.

The Atlantic surf clam ranked first by number and weight and averaged 38 n/coll. (5.6 kg/coll.) for the year. It was most abundant at the Landward I station where it averaged 127 n/coll. (16.7 kg/coll.). At the stations north, south, and Landward II of the Site (Fig. 8) the surf clam was common and the yearly average ranged from 18 to 38 n/coll. At the Site and landward of Brigantine Ridge, the surf clam was sparse and averaged 2 to 3 n/coll.

The sand dollar ranked second by number, sixth by weight, and averaged 6 n/coll. (37 g/coll.) for the year. It occurred exclusively at the Brigantine II station (88 n/coll.) and at the Ridge (1 n/coll.).

The Atlantic moonsnail ranked third in abundance and weight and averaged 4 n/coll. (98 g/coll.) for the year. It ranged from 1 to 6 n/coll. at all ocean stations.

Little Egg Inlet

A total of 47 collections taken in the Inlet at four stations yielded 30,698 specimens of 35 taxa which weighed 425 kg. Species composition and physicochemical parameters for each collection are given in Appendix Tables 16 to 20. Seasonal summaries of monthly collections appear in Tables 50 to 54. The Atlantic surf clam ranked first and comprised 64% of the weight and 5% of the specimens. Other major species were the blue mussel (29% weight, 93% number); starfish, <u>Asterias</u> <u>forbesii</u> (3%, 0.5%); and rock crab (2%, 0.9%). The remainder was accounted for by 31 taxa, each of which comprised less than 1% of the total weight.

Significant differences were found between major components of Inlet stations. The most abundant species (Atlantic surf clam, blue mussel, rock crab, and starfish) at Inlet stations were compared by ranking their abundance each month at each station. A significant difference between stations was found for all species except the rock crab.

The blue mussel ranked first by number and was collected only at stations south of Stake "96" and near "F" buoy. South of Stake "96" it had a yearly average of 2,592 n/coll. (11.2 kg/coll.); near "F" buoy, it averaged 1 n/coll. (3 g/coll.).

The Atlantic surf clam ranked second in abundance and was collected at all stations. It was most abundant on a sandbar east of Stake "96" where it averaged 91 n/coll. (16.6 kg/coll.). At the other stations, it averaged from 1 to 9 n/coll. for the year.

The starfish ranked third in abundance and was collected at all stations. It was most abundant south of Stake "96" where its yearly average was 13 n/coll. At other stations, the yearly average ranged from less than 0.5 to 1 n/coll.

Ocean versus Inlet

Ocean and Inlet stations with sandy substrate were compared by ranking the densities of major components and of abundant species and no differences ($P \leq .05$) were found. Aggregations of blue mussels which occurred in the Inlet differed significantly from the fauna found on sandy substrates.

Little Sheepshead Creek

Eleven collections at the Little Sheepshead Creek station (zone 2210) yielded 420 specimens of 24 taxa which weighed 26 kg (Table 54). The hard clam (23 n/coll, 2.1 kg/coll.), spider crab (2 n/coll., 12.6 g/coll.), and blood ark, Anadara ovalis, (1 n/coll., 32 g/coll.) comprised 97% of the weight. This station yielded different species than were encountered in the Inlet or ocean.

## Discussion

In the ocean, Atlantic surf clam, horseshoe crab, lady crab, Atlantic moonsnail, rock crab, and sand dollar comprised 99.5% of the weight collected. These and the following comprised 95.2% of the number collected: long-armed hermit crab, northern moonsnail, and the polychaete, Lumbrineris fragilis. Bottom sediments at all ocean stations were composed of sand with a small percentage of silt and were similar. Although no major differences between stations were detected, the Atlantic surf clam was most abundant at the Landward I station. The largest number of taxa (26) was collected at the Site and the smallest (12) was taken on the Ridge. An average of 55 n/coll. was taken from all stations in the ocean and 12 n/coll. was taken at the Site.

In the Inlet, the blue mussel, Atlantic surf clam, rock crab, and starfish comprised 97.1% of the total weight of specimens and 98.9% of the total number. The bottom sediment varied from station to station which in part, accounted for the difference between the densities of the major components and dominance by different species at each station. The station south of Stake "96" had the highest percentage of silt and dense aggregations of the blue mussel were present there. Many Atlantic surf clam occurred east of Stake "96" where the bottom was primarily sand. The station south of Stake "96" had the most taxa (29), and that off Little Beach had the least (6). No significant differences were found between densities of major components at stations in the ocean and in the Inlet. However, in the Inlet, the blue mussel formed dense aggregations which did not occur in the ocean.

In Little Sheepshead Creek, the hard clam, spider crab, and blood ark were the most common species by weight. The most abundant species by number were the hard clam, polychaete (*Hydroides dianthus*), and the spider crab.

## CLAM DREDGE SURVEY

### Introduction

On September 13, 14, 15, 16, and 27, a total of 45 samples was taken with the clam dredge in the Inlet and the vicinity of the Site. Samples were taken on a rectangular grid, approximately 5 statute miles wide and 8 miles long (Fig. 15). The grid was centered on the Site and extended from Holgate on the north to Brigantine Inlet on the south and from "D" buoy in Little Egg Inlet to the 50 foot contour east of the Site. An effort was made to take samples at 1 mile intervals.

The objectives were to determine the distribution, density, biomass, and life history information of the Atlantic surf clam and associated species.

## Materials and Methods

The clam dredge and methods for its use were described above. For the survey, two such dredges were bolted together to obtain two simultaneous replicate samples.

All samples were sorted in the field; everything was returned except small specimens of the Atlantic surf clam (less than 60 mm) and morrhua venus, *Pitar morrhuana*. Organisms were classified, enumerated, and weighed to the nearest 0.1 kg with a hand-held spring scale. All Atlantic surf clam were measured from small collections and a subsample of 150 individuals was measured from large collections. Measurements were made to the nearest mm with a vernier caliper.

A 500 cc sediment sample was taken with a ponar grab at each station. Grain size was estimated visually using a phi-size finder.

## Results

The collections yielded 10,063 specimens of 27 taxa which weighed 517 kg (Appendix Table 21). The Atlantic surf clam (29% of the total number, 88% of the total weight) and the sand dollar (63%, 7%) were dominant.

The 10 most numerous species (99% of the specimens taken) were the sand dollar; Atlantic surf clam; Atlantic moonsnail; smooth astarte, *Astarte castanea*; morrhua venus; rock crab; lady crab, *Ovalipes ocellatus*; long-armed hermit crab; New England nassa; and northern moonsnail. Distribution maps were plotted for these 10 species

(Fig. 16 to 24), the total number of organisms taken (Fig. 25), and the sediment type (Fig. 26). The average density for all organisms was 0.66 $n/m^2$ (0.003 to 7.7 $n/m^2$). The area near the Site (stations 20, 21, and 22) exhibited low densities of 0.04, 0.03, and 0.003 $n/m^2$.

The sand dollar was collected at depths from 20 feet to 37 feet; 86% were taken in depths greater than 40 feet. It was most dense at Station 23 (7.8 $n/m^2$) and was also common at Stations 28, 29, 30, 32, and 35. The average density was 0.38 $n/m^2$. Low densities of 0.03, 0.002, and 0 $n/m^2$ were taken near the Site.

The Atlantic surf clam was collected at all depths; 94% were taken between 10 and 30 feet. It was most dense at station 1 (1.6 $n/m^2$) and was common at stations 3, 4, 9, 14, 2, 46, 48, and 49. The average density for all stations was 0.18 $n/m^2$, but the average density for stations of depths less than 20 ft was 0.51 $n/m^2$.

The mean length of 1,133 Atlantic surf clam was 101 mm and the mode was 102 mm (Table 55 and Fig. 27). At depths less than 20 ft, the mean was 98 mm and at depths greater than 20 ft, it was 127 mm. Clams of commercial size (greater than 100 mm) comprised 55% of those taken. Individuals less than 50 mm comprised 5% of the total. The remainder were in the 50-100 mm size range.

The Atlantic moonsnail was collected at depths from 14 to 20 ft. It was most abundant at station 9 (0.25 $n/m^2$) and averaged 0.02 $n/m^2$. It was sparse at the Site where densities were 0.003, 0, and 0 $n/m^2$.

The smooth astarte was present at depths from 36 to 57 ft. Its highest density was encountered at 56 ft at station 39 (0.08 $n/m^2$).

Average density was 0.01 $n/m^2$. It was absent from the Site.

The morrhua venus was collected at depths from 36 to 56 ft. It was most dense at station 24 (0.07 $n/m^2$) and averaged 0.004 $n/m^2$. None were found near the Site.

The rock crab was present at depths from 23 to 56 ft. It was most dense at station 27 (0.06 $n/m^2$) and averaged 0.004 $n/m^2$. None were taken near the Site.

The lady crab was collected at depths from 16 to 47 ft. It was most dense at station 47 (0.02 $n/m^2$) and averaged 0.01 $n/m^2$. It was sparse at the Site (0.001, 0, and 0.003 $n/m^2$).

The long-armed hermit crab was collected at depths from 10 to 56 ft. It was most dense at station 9 (0.03 $n/m^2$) and averaged 0.01 $n/m^2$. None were taken near the Site.

The New England nassa was present at depths from 18 to 56 ft. It was most dense at station 9 (0.07 $n/m^2$) and averaged 0.01 $n/m^2$. None were collected near the Site.

The northern moonsnail was collected at depths from 14 to 50 ft. It was most dense at station 28 (0.05 $n/m^2$) and averaged 0.004 $n/m^2$. Low densities of 0.001, 0.002, and 0 $n/m^2$ were found near the Site.

## Discussion

Haskin and Merrill (1974) reported generally higher densities of surf clam in the Little Egg Inlet area than were observed in the present study. This may be because (1) their collections were taken with a commercial hydraulic dredge which digs deeper than a dry dredge and caused their estimates of density ($n/m^2$), weight ($kg/m^2$), and length (mean length) to be greater than ours; (2) in some cases their tow distances may have been underestimated and therefore densities overestimated (personal communication, Harold Haskin); (3) the smaller mesh of the dry dredge facilitated collection of small clams not taken by them.

In September, low densities of organisms susceptible to collection with the clam dredge were found at the Site. No aggregations of Atlantic surf clam occurred in the immediate vicinity of the Site but high densities were found landward of the Site.

Populations of Atlantic surf clam of commercially harvestable size and density exist on the shoals bordering Beach Haven, Little Egg, and Brigantine inlets. These aggregations were from 10 to 100 times as dense at those outside the 20 ft contour. The mean length was smaller inside the 20 ft contour.

## TRAWL

### Introduction

Collections were made in the vicinity of the Site with a 25-ft semiballoon trawl since February 1972. In 1974, the program was expanded to include monthly collections in the Great Bay-Mullica River estuary; night collections; and simultaneous replicate tows. The objectives were to determine relative abundance, biomass, and temporal and spatial distributions of demersal fish and motile benthic invertebrates in the vicinity of the Site and in the estuary.

## Materials and Methods

The gear, methods of collection, sampling stations, and lab techniques are presented in the section for the 25-ft trawl program in Volume I.

Large collections of some species (ie. lady crab, rock crab, sand dollar, *Echinarachnius parma*, and starfish) were counted, measured, sexed (where applicable), weighed, and released in the field. Subsamples were preserved for life history studies. In the field, weights were taken to the nearest 0.1 kg with a hand-held spring scale.

The sex and reproductive condition of all crabs were noted. The carapace widths of the rock crab and the blue crab, *Callinectes sapidus*, were measured to the nearest mm with a vernier caliper.

Most collections were preserved and invertebrates were identified, counted, and weighed in the lab. Wet weights were measured to the nearest gram using an Ohaus triple beam balance. Molluscan egg cases, *Crepidula* spp. , cnidarians (except Actiniaria and *Cyanea capillata*), ctenophores, and bryozoans were noted as present. Nomenclature usually followed that of Gosner (1971).

Species diversity of individual collections was calculated using the Shannon Weaver Index (Pielou 1966 ). Seasonal and monthly diversities are averages of individual values.

The Wilcoxon signed rank test (Tate and Clelland 1957) was used to test for differences between day and night hauls in the ocean.

# Results

## Ocean

In the vicinity of the Site in 1974, 187 collections were taken in the day and 15 were made at night (Appendix Table 22).

A total of 85,186 specimens (60 taxa), which weighed 471.8 kg was collected in the ocean (Tables 56 and 57). Species diversity of individual collections ranged from 0.08 to 2.12.

Decapods constituted 67% of the total number of specimens and 35% of the total weight. The sand shrimp comprised 88% of the decapods and accounted for 10% of the decapod weight. The rock crab accounted for 57% of the decapod weight and the lady crab comprised 20%; together they composed 7% of the decapod specimens.

Echinoderms were the second most abundant organisms in ocean trawl collections and accounted for 19% of the total number and 21% of the total weight. The most abundant were the sand dollar (71%) and starfish (29%).

The 10 most abundant species by weight in ocean trawl samples were the horseshoe crab, (33% of the total weight and 0.1% of the total number); rock crab (20%, 4%); sand dollar (15%, 1%); lady crab (7%, 1%); starfish (7%, 5%); Atlantic long-finned squid, <u>Loligo pealei</u> (5%, 9%); sand shrimp (4%, 59%); lion's mane jellyfish (0.2%, 0.1%); blue crab (0.2%, 0.1%); and the spider crab, <u>Libinia emarginata</u> (0.2%, 0.1%).

Of the 10 most numerous species in the ocean, the sand shrimp, sand dollar, rock crab, starfish, long-armed hermit crab, and New England nassa appeared every month (Table 58). The sand shrimp averaged 25 n/coll. for the year. Peaks in abundance occurred in February and July. The sand dollar averaged 56 n/coll. and was most abundant in the spring. Most were collected seaward of the Ridge (zones 5350 and 5450) but it was occasionally encountered inside the Brigantine ridge (zones 5280 and 5380). It averaged 117 n/f (number per collections in which it appeared). The starfish averaged 23 n/coll. and its density remained relatively stable throughout the year. The rock crab averaged 16 n/coll. for the year. Peaks in abundance were recorded in February and July. The long-armed hermit crab averaged 9 n/coll. for the year and was most abundant in the summer. The New England nassa averaged 1 n/coll.

The horseshoe crab, lady crab, and blue crab were present in the vicinity of the Site during most of the year. The horseshoe crab averaged less than 1 n/coll. for the year. It was most abundant in the spring and summer, and was absent in January and February. The lady crab was present in all seasons except winter. It averaged 6 n/coll. for the year and was most abundant in the summer and fall. The blue crab was not collected in the vicinity of the Site in January, March, May, and October. It averaged less than 1 n/coll. for the year and was most abundant in November.

The Atlantic long-finned squid was present in the ocean from May through December. It was most abundant in July and September and averaged 104 n/f.

The brown shrimp, Penaeus aztecus, was taken from August through November. It was most abundant in October, and averaged 2 n/f.

Great Bay-Mullica River estuary

A total of 44 collections was taken on a transect from the Mullica River through Great Bay to Little Egg Inlet (Fig. 8, Vol. I). Eleven were taken in each of the following areas: Little Egg Inlet (zone 1015), the intracoastal waterway in Great Bay (zone 1045), the inner portion of Great Bay (zone 1075), and the lower Mullica River (zone 1510). See Appendix Table 23.

A total of 120,892 specimens (59 taxa), which weighed 172.8 kg, was collected in the estuary (Tables 59 and 60). Species diversity ranged from 0.01 to 1.92.

The blue mussel comprised 50% of the total number and 44% of the total weight.

Decapods made up 49% of the total number and 44% of the total weight. Sand shrimp comprised 98% of the number and 36% of the weight of decapods taken. The rock crab and blue crab each accounted for 1% of the decapod number and together accounted for 52% of the decapod weight. The grass shrimp accounted for 1% of the decapod weight and 4% of the number.

The 10 most abundant species by weight were the blue mussel (27% of the total weight, 50% of the total number); boring sponge, Cliona sp. (16%, -); rock crab (16%, 0.1%); sand shrimp (16%, 45%); blue crab (7%, 0.1%); horseshoe crab (4%, 0.1%); lady crab (4%, 0.1%); redbeard sponge, Microciona prolifera (2%, -); starfish (2%, 1%); and hard clam (1%, 0.1%). The blue mussel, sand shrimp, rock crab, starfish, and blue crab which also ranked among the 10 most abundant species by number were present throughout most of the year, and together comprised 87% of the biomass collected in the Bay in 1974 (Table 61).

The blue mussel was found in localized aggregations in association with the mud crab and starfish. These communities were present all year but were only encountered sporadically. The blue mussel averaged 30,348 n/f (the number per collection in which it occurred), the starfish 41 n/f, and the mud crab 13 n/f.

The sand shrimp, blue crab, and long-armed hermit crab were taken every month. The sand shrimp averaged 267 n/coll., the blue crab 2 n/coll., and the long-armed hermit crab 3 n/coll. The sand shrimp was most abundant in winter and the blue crab was most common in spring.

The rock crab (2 n/coll.), lady crab (1 n/coll.), and horseshoe crab ($\leq 1$ n/coll.) appeared in small numbers in the Bay. The rock crab was absent in May and the lady crab was absent in February and August. The horseshoe crab was present in five of the 11 months sampled.

The brief squid, Lolliguncula brevis, appeared from July through November and was most common in September; it averaged 16 n/f for these months.

Day/Night Comparison

Some 38 species were taken in day/night collections in the vicinity of the Site; eight species comprised most of the biomass and appeared in 10 or more replicate pairs. Total number, total weight, and individual numbers of New England nassa, Atlantic long-finned squid, sand shrimp, long-armed hermit crab, rock crab, lady crab, sand dollar, and starfish were compared in day/night paired samples (Table 62).

The total number of specimens per collection was significantly ($P \leq .05$) greater at night. Most of the day/night differences were due to a 100 fold increase in number of sand shrimp collected at night. The number of Atlantic long-finned squid collected during the day was 50 times greater than during the night. The rock crab was usually more numerous in the day, but the difference was not significant ($P \leq .05$). Total weight taken was usually greater at night but this difference was not significant.

## Discussion

The macroinvertebrate community in the estuary and the vicinity of the Site changed seasonally and each area was utilized at different times of the year by different groups. Abundance of some species, such as the sand dollar and starfish, was primarily affected by success of spawning and settlement, and showed only small seasonal variation. Other species exhibited dramatic changes in abundance, particularly the decapods and squids which moved in and out of the estuary and offshore and inshore in distinct patterns.

The resident populations of the estuary and ocean were different. The sponges, *Cliona* sp. and *M. prolifera*, were found exclusively in the Bay and the sand dollar was found only in the ocean. Estuarine species such as the mud crab and blue crab were rarely found in the ocean and marine species such as the lady crab were rarely found in the estuary. A few residents such as the sand shrimp were ubiquitous.

The sand dollar, starfish, and blue mussel were present all year and exhibited little seasonal change in density. These species were present in localized areas of suitable substrate. The sand dollar preferred coarse sand in the ocean; the blue mussel preferred wrecks in the ocean and channel banks and hard substrates in the Bay and Inlet.

In winter, diversity values were low in both the ocean (0.81) and estuary (0.74) when a few species dominated the communities in each area. Large rock crab migrated from offshore to the vicinity of the Site and Inlet and were present in densities as high as 108 n/f. Large sand shrimp were numerous in the nearshore ocean and in the lower Mullica River in densities as high as 547 n/f and 8,995 n/f, respectively.

In spring, the numbers of sand shrimp and rock crab were less and the diversity values increased to 1.10 in the ocean and to 1.06 in the estuary. The higher diversity also coincided with the appearance of species which had not been present in winter. The blue crab had high densities in the estuary (57 n/f); the horseshoe crab was taken about equally in the ocean (3.2 n/f) and estuary (4 n/f); and the lady crab was common in the vicinity of the Site ( 5 n/f) and Inlet ( 1 n/f). Adult Atlantic long-finned squid and squid eggs were first collected in the ocean in May.

In summer, the diversity in the ocean dropped to 0.94 and that in the estuary rose to 1.12. The drop in the ocean value was caused, in part, by large numbers (1,116 n/f) of juvenile sand shrimp. Juveniles of both the rock crab and Atlantic long-finned squid were common. The lady crab and long-armed hermit crab were abundant in the ocean at this time. The brown shrimp and gravid blue crab were present in the vicnity of the Site. The increase in the diversity in the estuary was partially due to the appearance of southern species such as the brief squid and the lesser blue crab, *Callinectes similis*.

In fall, diversity values in the ocean (1.22) and the estuary (1.40) were highest for the year. Sand shrimp and rock crab were of larger size but their numbers were lower. Adult rock crab began to move inshore and were common in the vicinity of the Site in late fall. The brief squid and lesser blue crab, which were only present in the Bay in summer, appeared in both the Bay and ocean in fall. The blue crab, horseshoe crab, lady crab, and Atlantic long-finned squid decreased in numbers in early fall and were absent from ocean and estuarine collections by December.

## COMMERCIAL SHELLFISHERIES

Thirteen shellfishes were taken commercially in the ocean and bays along the New Jersey coast in 1974. Their value ($9.3 million) accounted for 50% of the total commercial landings in New Jersey. The five most valuable shellfishes were the Atlantic surf clam, American lobster, hard clam, eastern oyster, and blue crab. These comprised 91% of the value of shellfish landings (Table 63). Shrimp were taken in 1972 and 1973 but were not landed in 1974.

Atlantic County landings accounted for 21% of the value of the New Jersey landings, an increase of 5% over the 1973 value. The Atlantic surf clam, American lobster, and hard clam comprised 97% of the value of the Atlantic County landings.

In 1974, 22.6 million lb of the Atlantic surf clam, with a dockside value of $2.95 million, were landed in New Jersey; 28% of the catch was landed in Atlantic County. The Atlantic surf clam accounted for 36%

of the value of all commercial landings. The fishery in New Jersey was discussed previously by Thomas and Milstein 1973 and Garlo et al. 1974.

Some 1.2 million lb of American lobster valued at $1.9 million were landed in New Jersey; 10% of this catch was landed in Atlantic County.

A total of 1.7 million lb of hard clam worth $1.7 million was taken commercially from bays in New Jersey. The hard clam was the most valuable species landed in Atlantic County and those landed in Atlantic County comprised 45% of the value and nearly 50% of the weight of those landed in the State.

New Jersey landings of the eastern oyster totaled 1 million lb and were valued at $1 million. None were landed in Atlantic County, although some (1%) were taken from lots in the Mullica River.

State landings of blue crab amounted to 2.9 million lb valued at $724,000. Cape May County accounted for most commercial landings; only 5% were from Atlantic County.

Conch, sea scallop, rock crab, and squid landed in New Jersey were valued at $797,896. They comprised 9% of the total value of shellfish taken; Atlantic County landings accounted for 3% of this total.